Facilitating Heliophysics Research by the Virtual Wave Observatory (VWO) Context Data Search Capability

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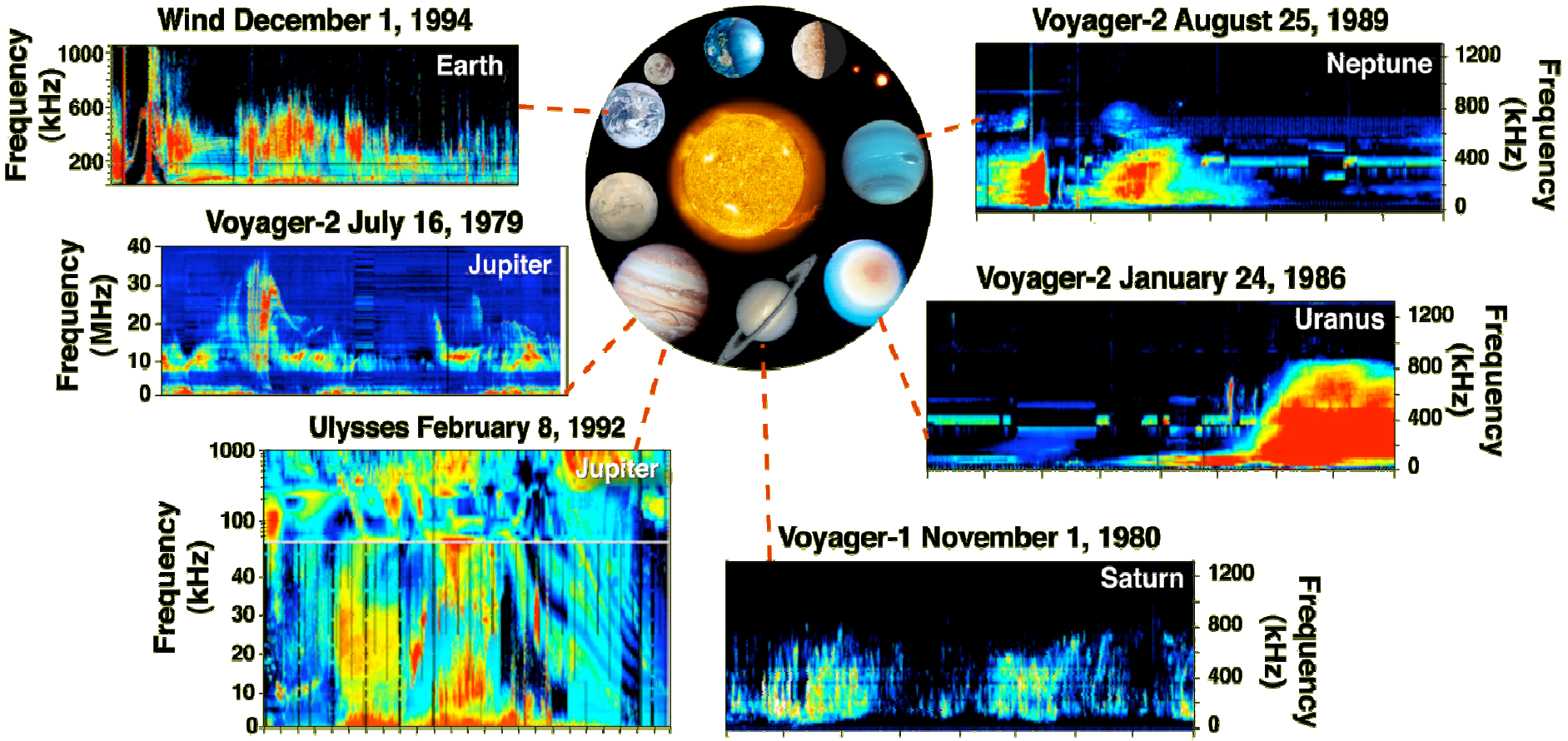
Presented at Fall AGU Meeting, December 14 - 18, 2009

Abstract

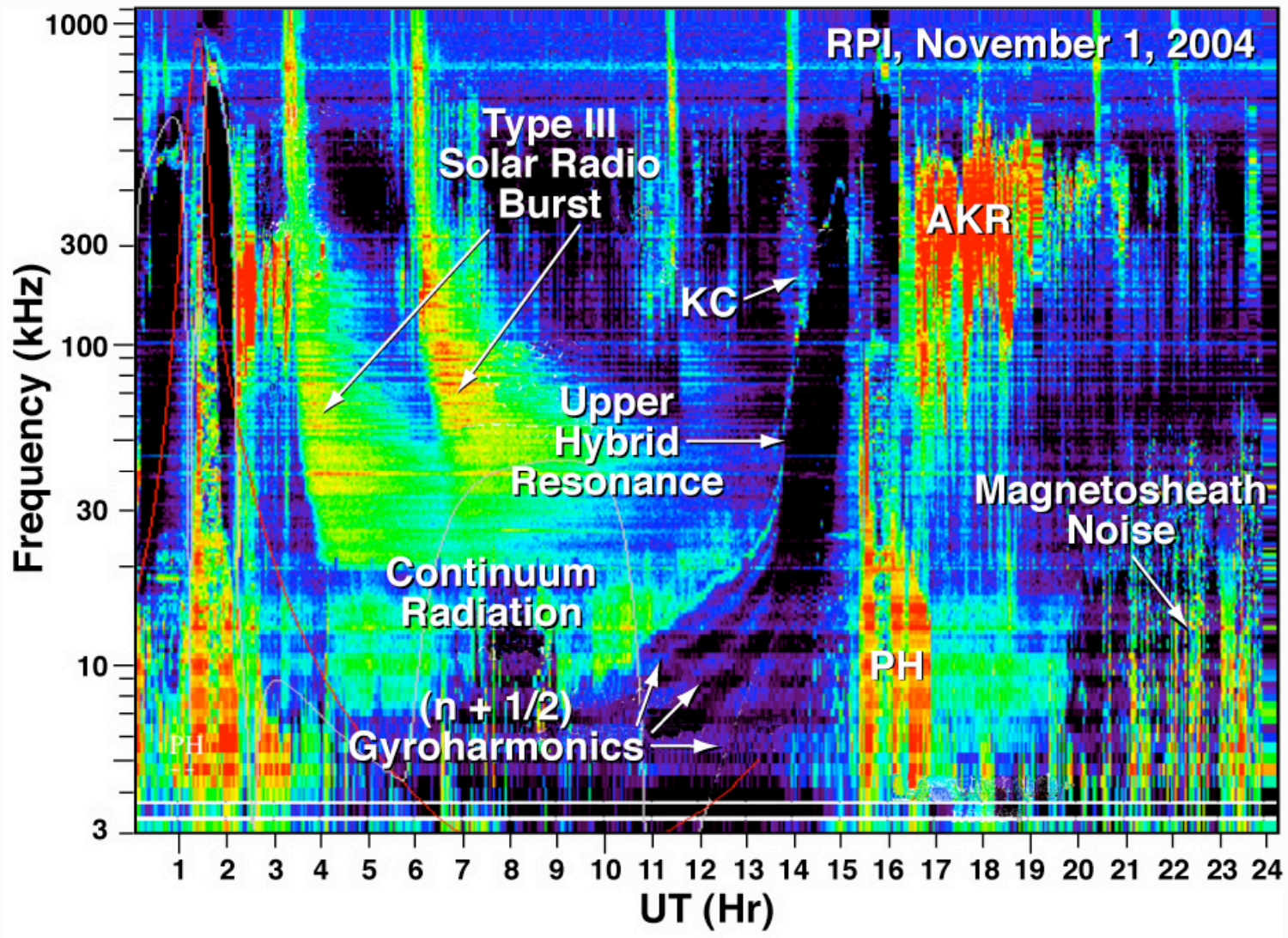
Wave phenomena, ranging from freely propagating electromagnetic radiation (e.g., solar radio bursts, AKR) to plasma wave modes trapped in various plasma regimes (e.g., whistlers, Langmuir and ULF waves) and atmospheric gravity waves, are ubiquitous in the heliosphere. Because waves can propagate, wave data obtained at a given observing location may pertain to wave oscillations generated locally or from afar. While wave data analysis requires knowledge of wave characteristics specific to different wave modes, the search for appropriate data for heliophysics wave studies also requires knowledge of wave phenomena. In addition to deciding whether the interested wave activity is electrostatic (i.e., locally trapped) or electromagnetic (with propagation over distances), considerations must be given to the dependence of the wave activity on observer's location or viewing geometry, propagating frequency range and whether the wave data were acquired by passive or active observations. Occurrences of natural wave emissions in the magnetosphere (e.g, auroral kilometric radiation) are often dependent also on the state (i.e., context) of the magnetosphere that varies with the changing solar wind, IMF and geomagnetic conditions. Fung and Shao [2008] showed recently that magnetospheric state can be specified by a set of suitably time-shifted solar wind, IMF and the multi-scale geomagnetic response parameters. These parameters form a magnetospheric state vector that provides the basis for searching magnetospheric wave data by their context conditions. Using the IMAGE Radio Plasma Imager (RPI) data and the NASA Magnetospheric State Query System (MSQS) [Fung , 2004], this presentation demonstrates the VWO context data search capability under development and solicits feedback from the Heliophysics research community for improvements.

Waves are Ubiquitous in the Heliosphere



- Electromagnetic, electrostatic, fluid-dynamical
- Freely propagating or trapped
- Different frequencies

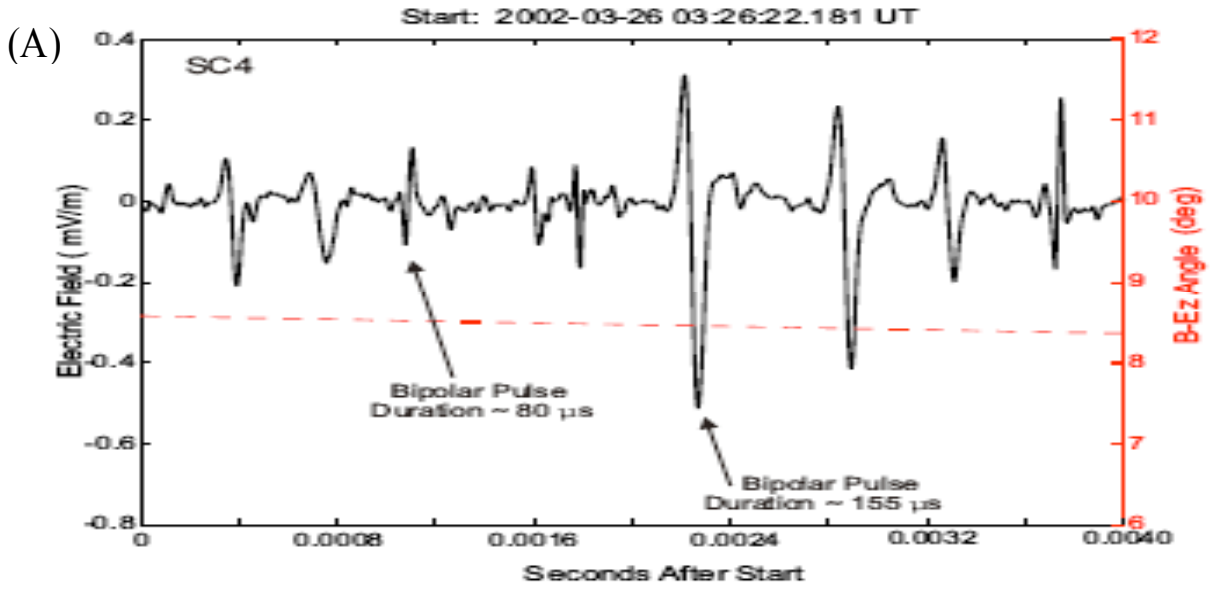
Wave Data Products



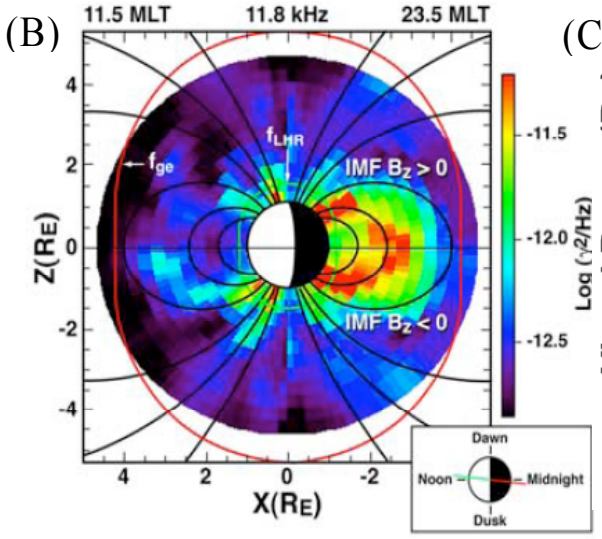
- Dynamics Spectrograms (as shown) are typical
- Multiple wave modes can occur at same frequency

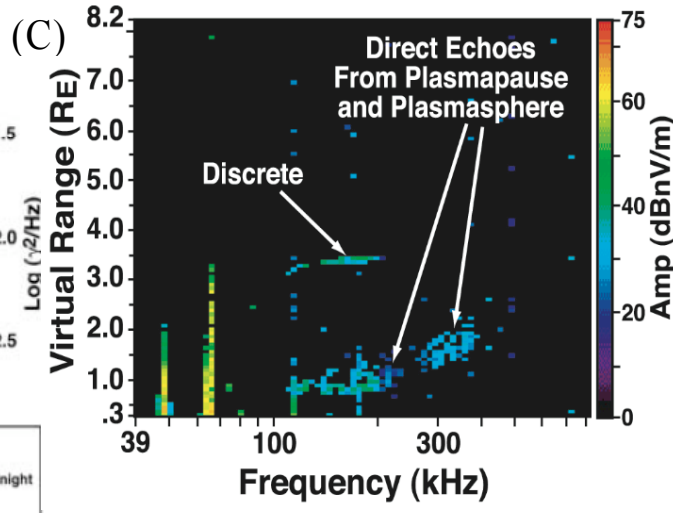
Other Wave Data Products

Time series



Wave map

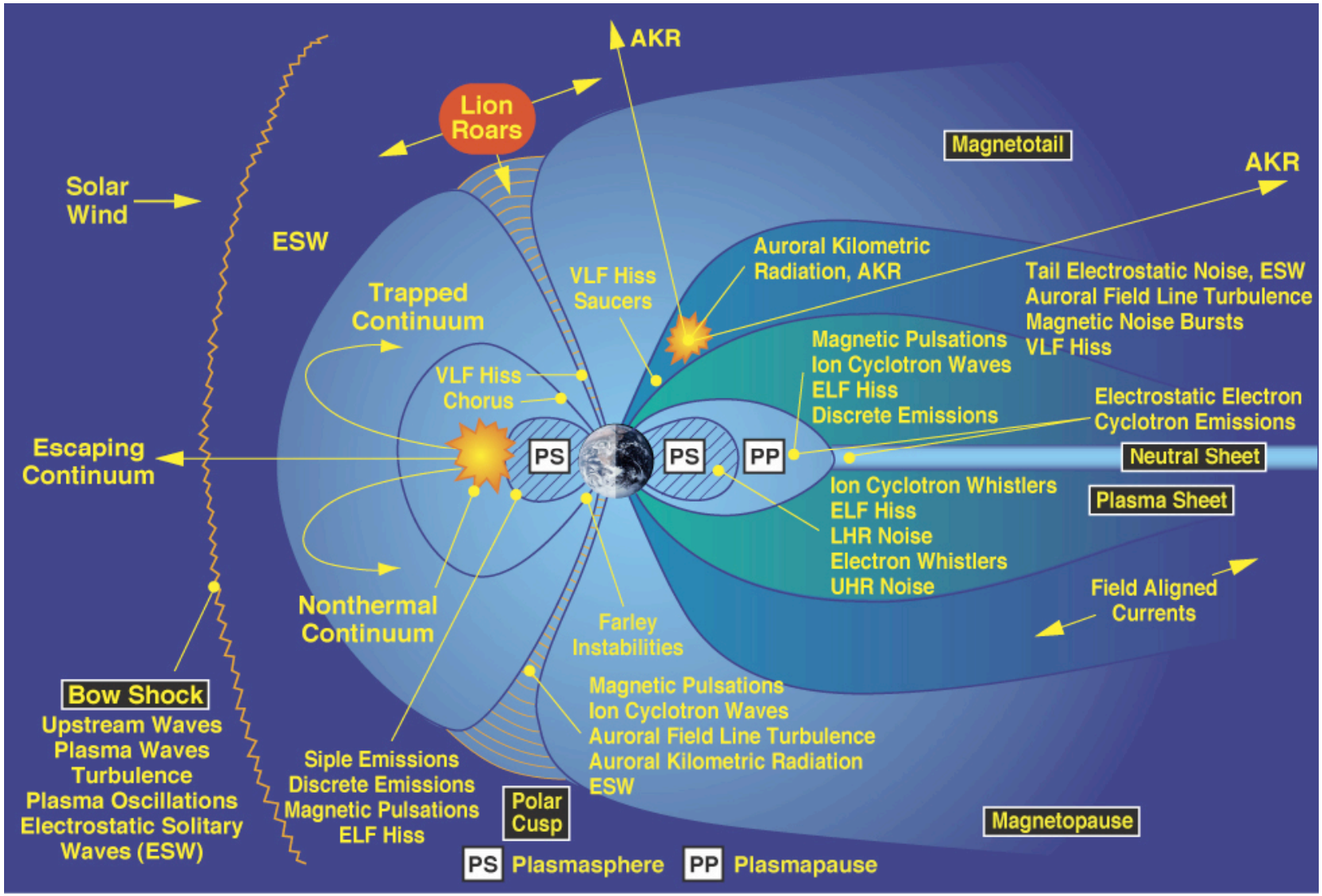




Plasmagram

From active radio sounding

Complex Wave Phenomena in Earth's Magnetosphere



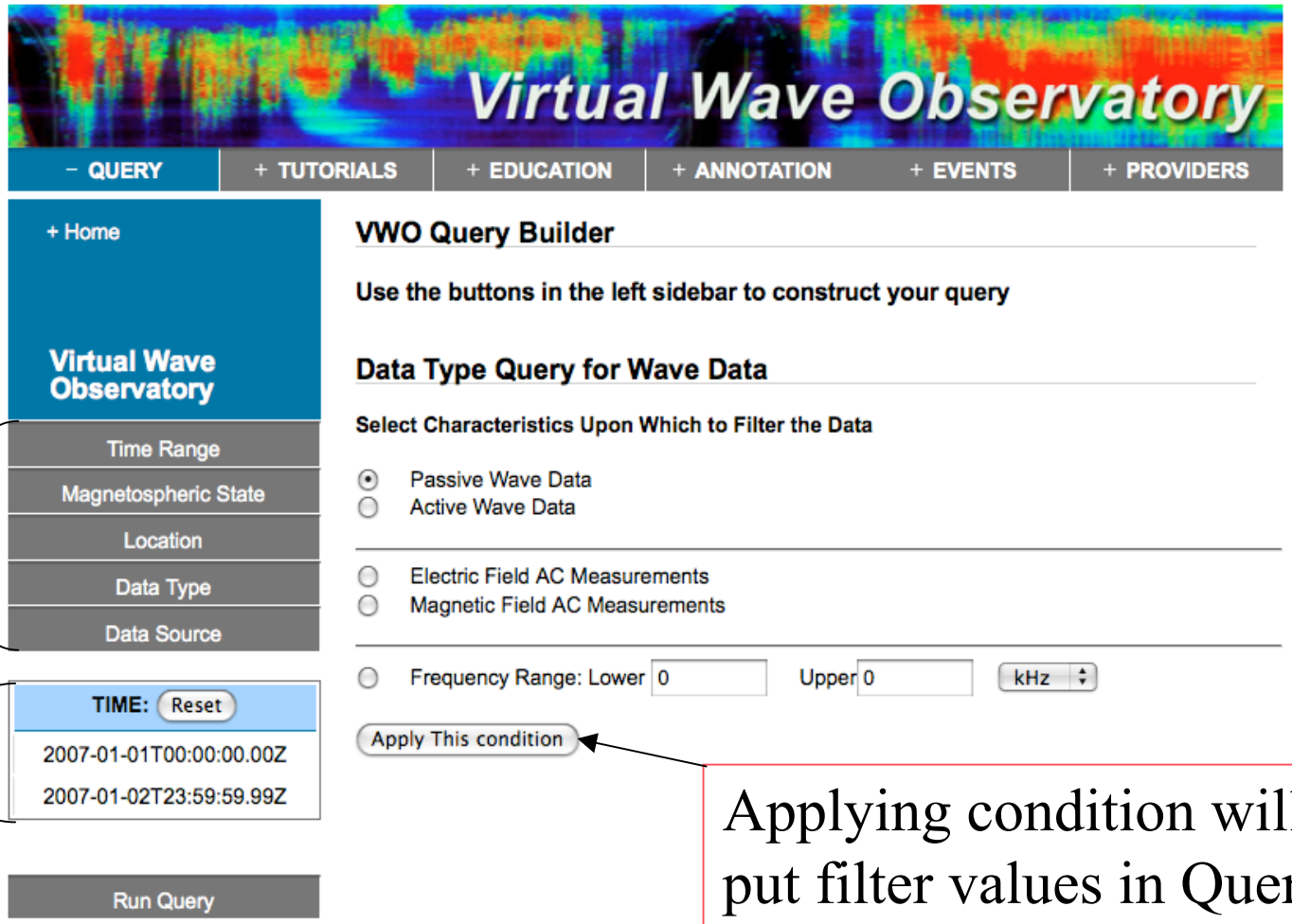
- Searching pertinent data for analysis can be challenging, particularly to non-experts

Querying Data With VWO

- By time, observing platforms, instruments, data products
  - Traditional data query (*e.g., CDAWeb*)
  - Can includes defined event lists
- By context
  - Magnetospheric state conditions
    - Sunspot numbers or F10.7 flux
    - Solar wind (velocity, P_{sw})
    - IMF
    - Multi-scale geomagnetic indices (K_p, D_{st}, AE)
  - Location
- Use Query Builder to construct complex data query

VWO Query Builder

(Under Construction)



Data query filters

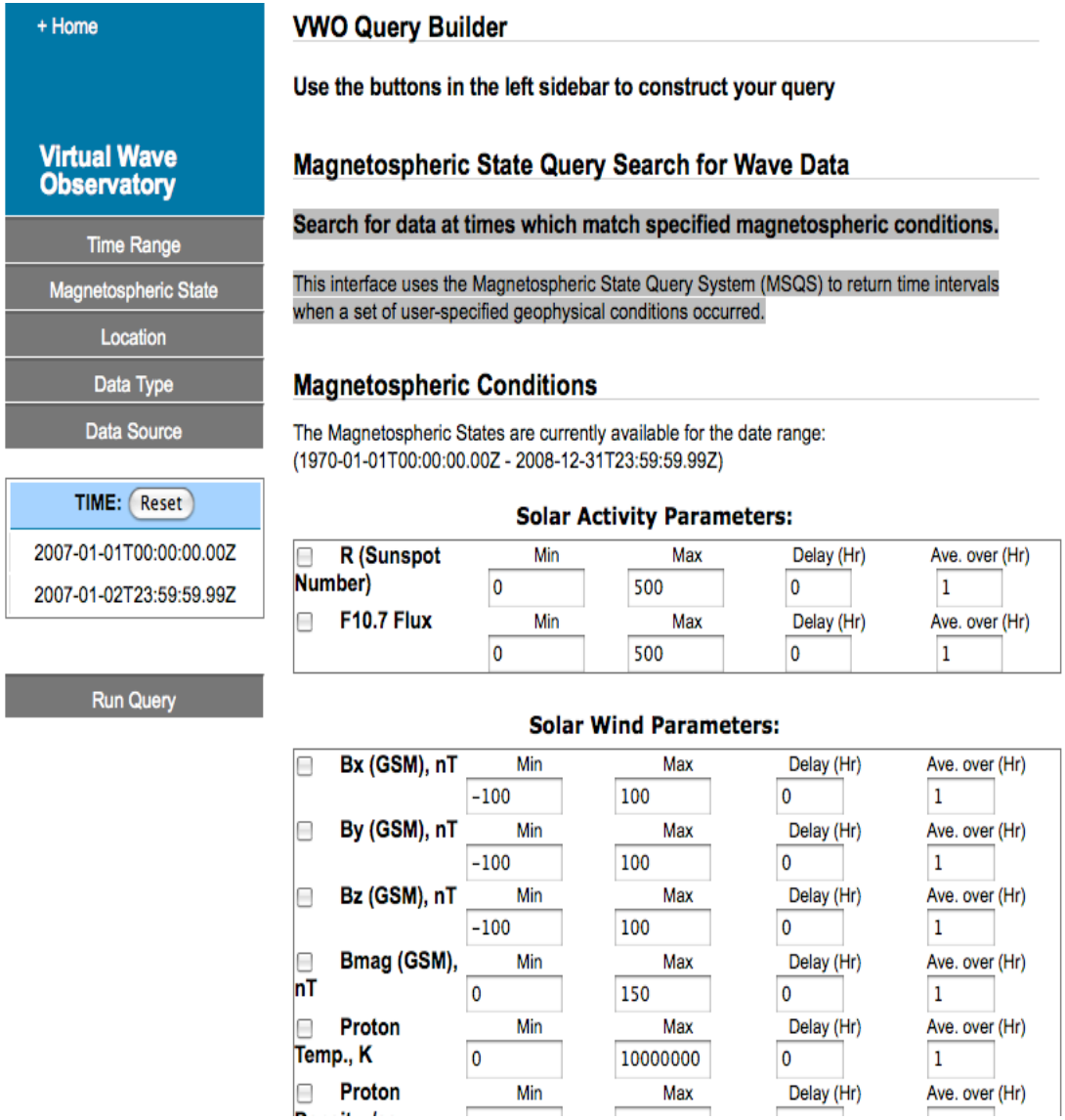
Query summary

Applying condition will put filter values in Query Summary

Example of querying data by *Time & Measurement Types*

Selecting Data by Magnetospheric State

- Currently *under construction*
- Search for data intervals under *user-specified* magnetospheric conditions
  - Use *Magnetospheric State Query System* (*MSQS*) to determine pertinent time intervals (within a time span)
  - Submit *MSQS* time intervals to data sources to get data



Magnetospheric-State Search Results

Step 1: MSQS Query:

Query Parameters:
2003-01-01 <= t < 2008-01-01
7.0 n/a <= Kp < 9.7 n/a; Shift: 0 (Hr); Ave. over: 1 (Hr)

Multi time-interval file: mt_9_21_2009_11h_46m_4938.txt

Step 2: Retrieved Multi-Satellite Wave Data

Satellite 1: IMAGE/RPI and Cluster/WHISPER combined dynamic spectrograms (CNRS
Satellite 2: IMAGE RPI daily dynamic spectrograms (NASA/GSFC)
Satellite 3: Cluster WHISPER Dynamic Spectrograms (CNR 6 hour resolution)

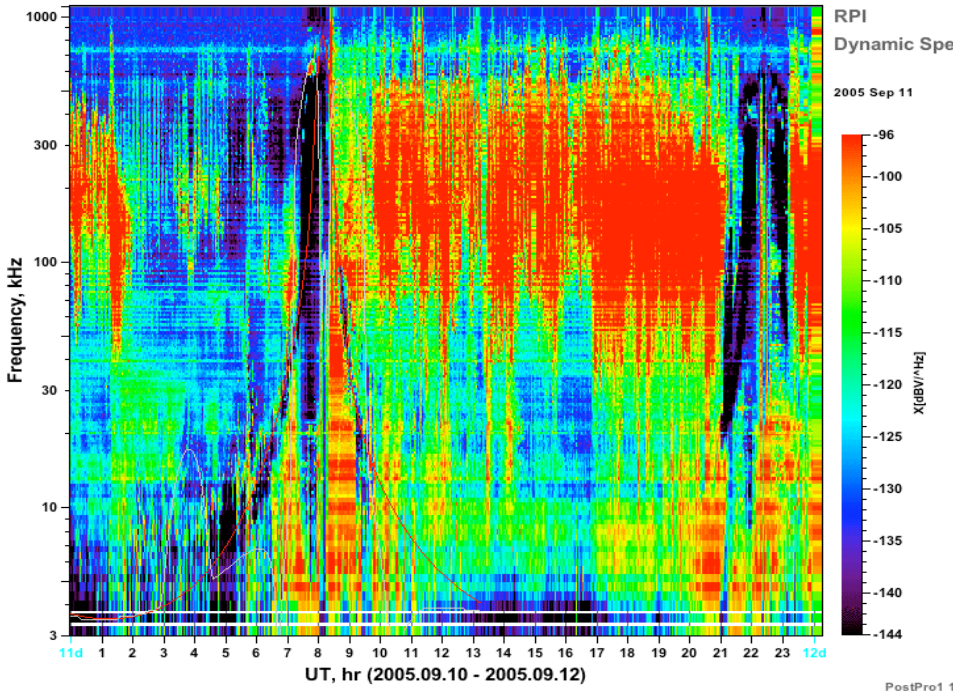
Time Intervals	IMAGE_RPI_Cluster_WHISPER Data	IMAGE_RPI Data	CLUSTER_WHISPER Data
2003-05-29 12:00 - 2003-05-30 02:59	cl_lin_200314912_200314918.gif cl_lin_200314918_200315000.gif cl_lin_200315000_200315006.gif	im_k1_rpi_20030529_ds.gif im_k1_rpi_20030530_ds.gif	jeu_cadre_affichage.php?day=29&month=05&year=2003&hdeb=12&hfin=18&public=1 jeu_cadre_affichage.php?day=29&month=05&year=2003&hdeb=18&hfin=24&public=1 jeu_cadre_affichage.php?day=30&month=05&year=2003&hdeb=00&hfin=06&public=1
2003-08-18 06:00 - 2003-08-18 08:59	cl_lin_200323006_200323012.gif	im_k1_rpi_20030818_ds.gif	jeu_cadre_affichage.php?day=18&month=08&year=2003&hdeb=06&hfin=12&public=1
2003-08-18 12:00 - 2003-08-18 17:59	cl_lin_200323012_200323018.gif	im_k1_rpi_20030818_ds.gif	jeu_cadre_affichage.php?day=18&month=08&year=2003&hdeb=12&hfin=18&public=1
2003-09-17 12:00 - 2003-09-17 14:59	cl_lin_200326012_200326018.gif	im_k1_rpi_20030917_ds.gif	jeu_cadre_affichage.php?day=17&month=09&year=2003&hdeb=12&hfin=18&public=1
2003-10-14 18:00 - 2003-10-14 23:59	cl_lin_200328718_200328800.gif	im_k1_rpi_20031014_ds.gif	jeu_cadre_affichage.php?day=14&month=10&year=2003&hdeb=18&hfin=24&public=1
			jeu_cadre_affichage.php?day=29&month=10&year=2003&hdeb=06&hfin=12&public=1

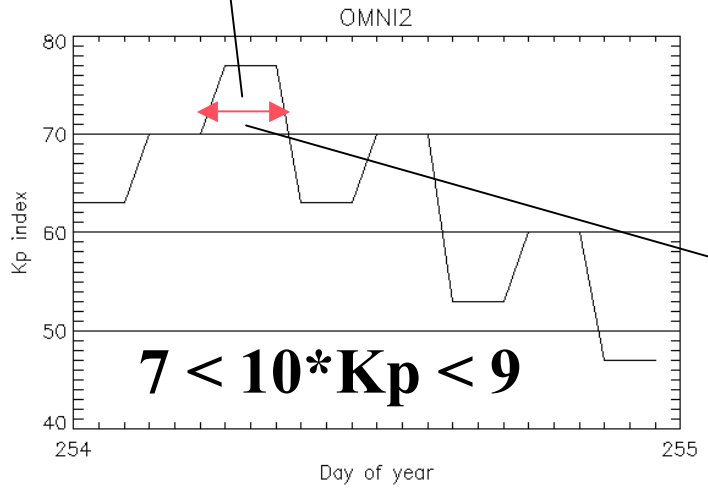
← Search condition summary

← Search results

Query Conditions	Query Results
$2003 < \text{Time} < 2008$	Geotail, IMAGE, Cluster
$7 \leq K_p \leq 9$	37 intervals (various durations)

IMAGE RPI Spectrogram





Cluster WHISPER Spectrogram

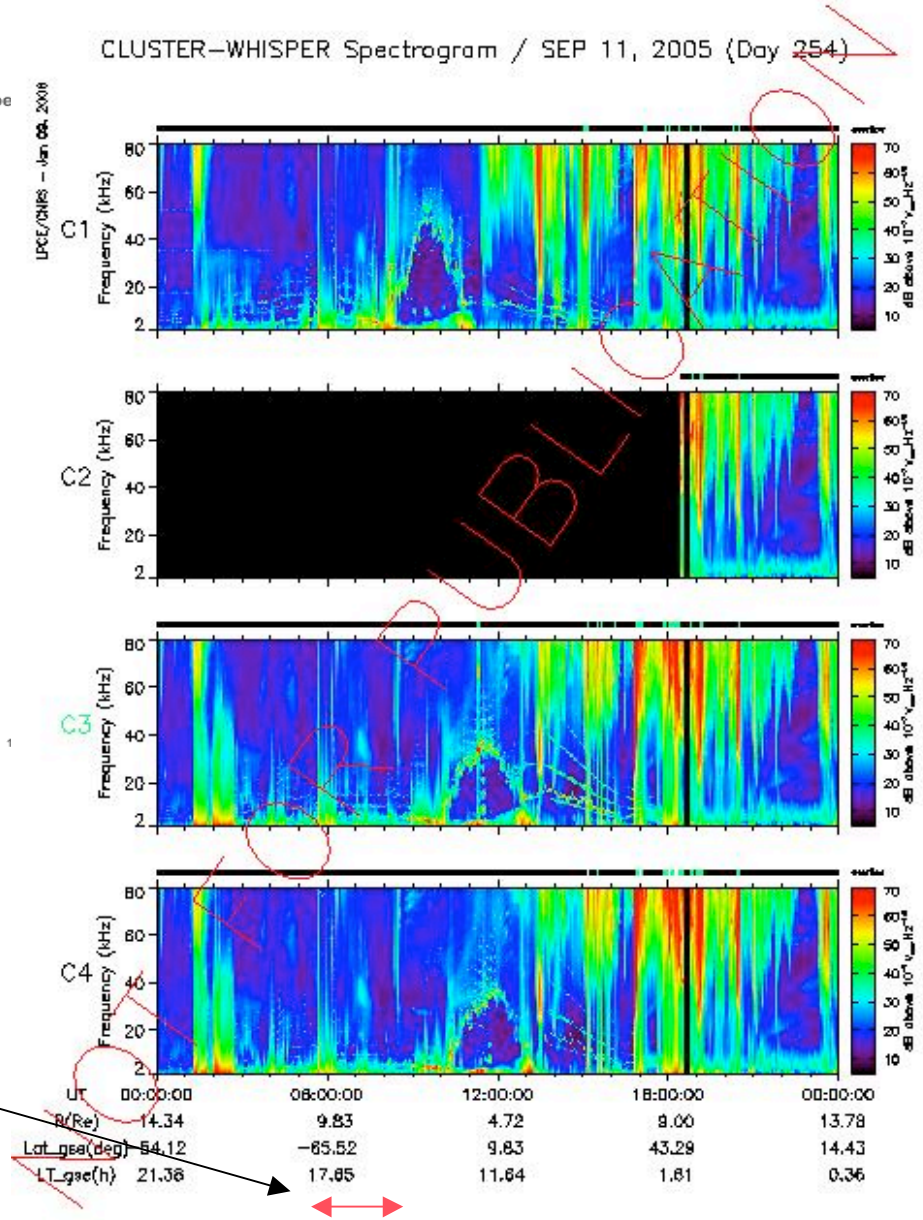


IMAGE &
Cluster Orbits
Sept 11, 2005
0600-1000 UT

Kp > 7

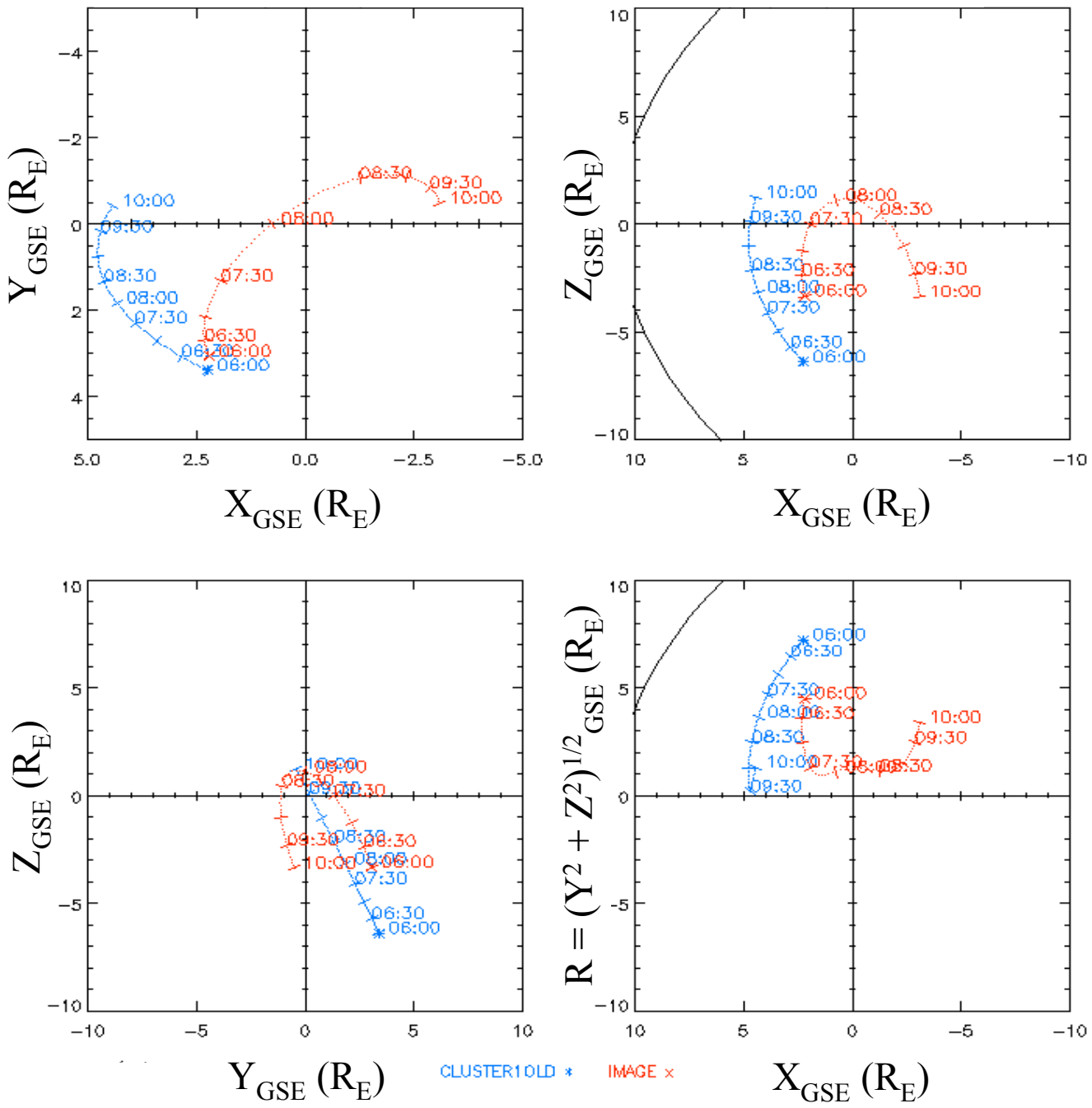
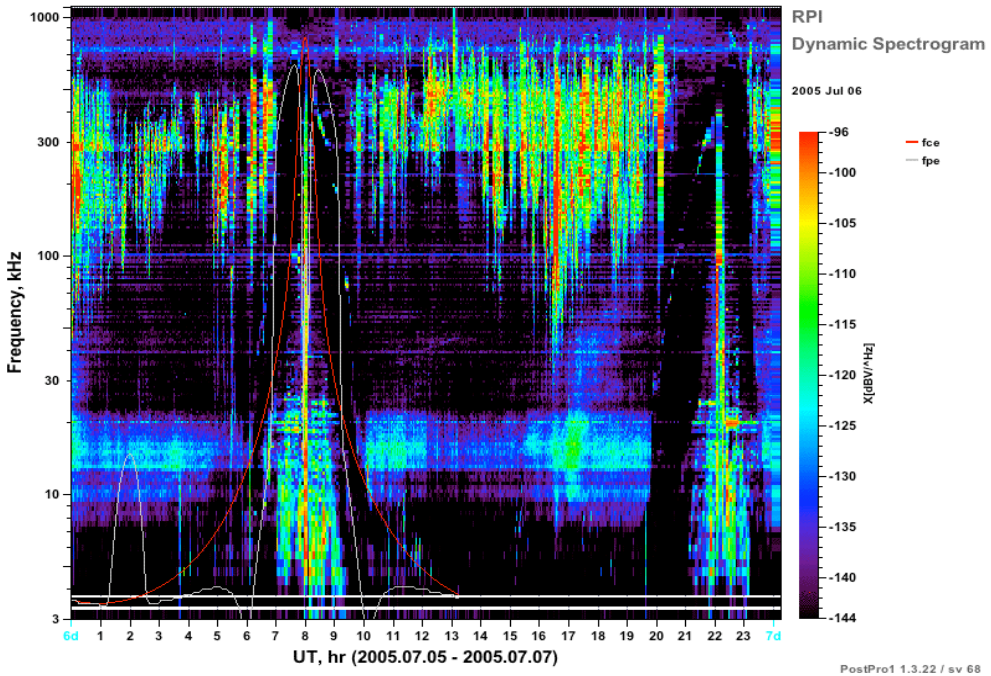
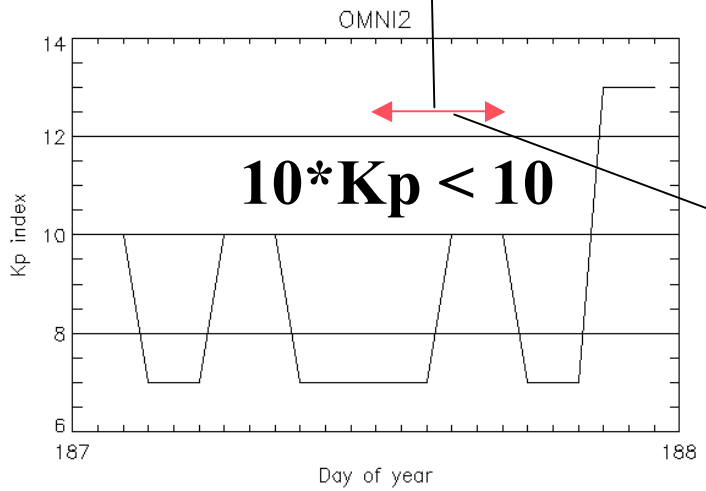


IMAGE RPI Spectrogram





Cluster WHISPER Spectrogram

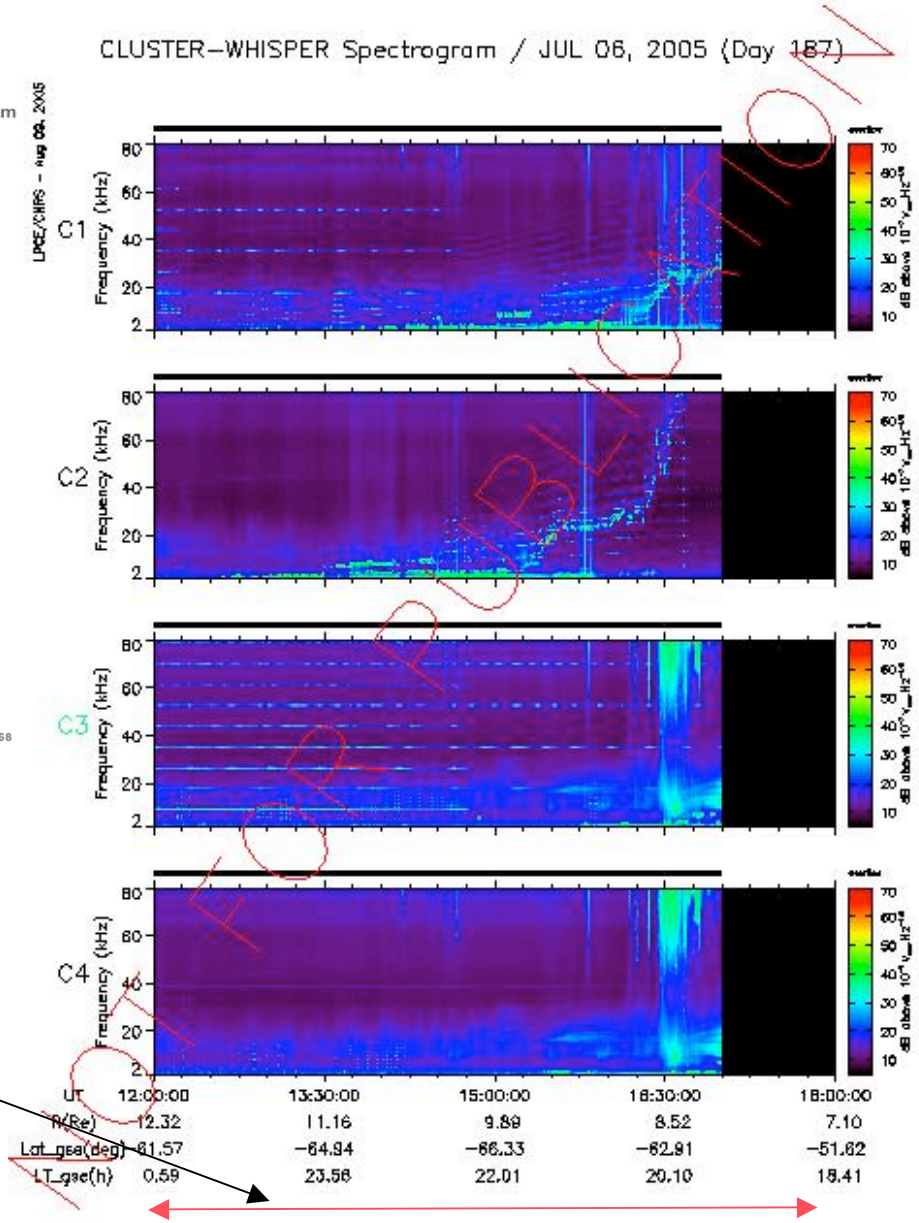
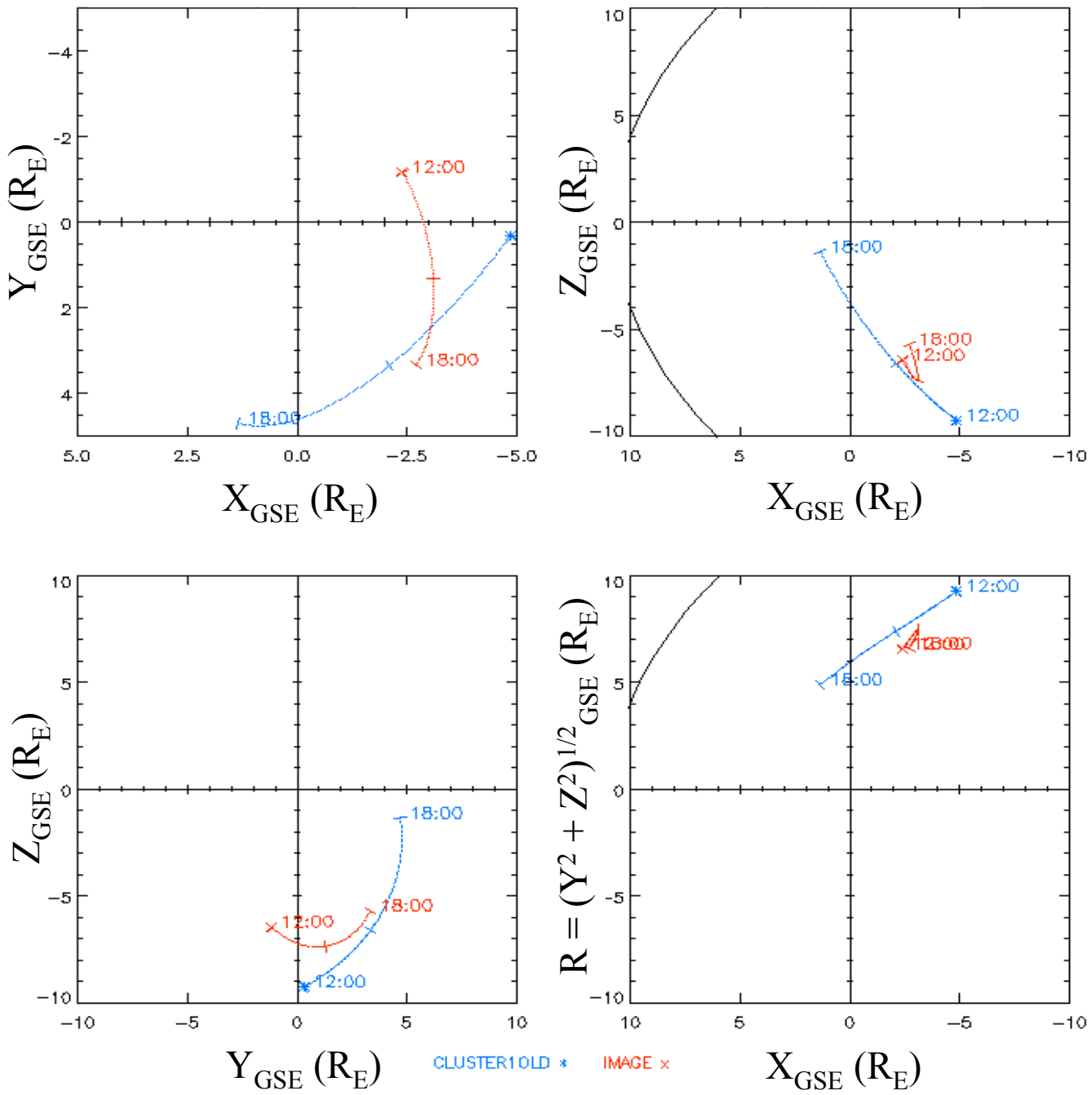


IMAGE &
Cluster Orbits
July 6, 2005
1200-1800 UT

Kp < 1



Summary

- Wave phenomena occur in all Heliophysics regimes
- Search for wave data can be challenging
  - Spectral data are not time series
  - Multiple wave phenomena can appear in same frequency range
  - Wave signals can be generated locally or remotely
  - Data selection requires knowledge of wave physics/phenomena
    - EM, ES, polarization, dispersion (cutoff, resonance) & propagation
  - Wave detections depend on space environmental conditions & observing locations
  - Diverse data products/sources (active, passive, space- & ground-based)
- VWO addresses these challenges in part by developing context data search, for examples, by magnetospheric state conditions and observing locations